SMARTSNAP: A new device to aid in the reduction of bycatch mortality in longline fisheries

Nieblas AE[1], Rouyer T[2], Bonhommeau S[3], Boyer A[1], Chanut J[1], Derridj O[2], Brisset B[3], Evano H[3], Wendling B.[4], Boguais A[5], Peressinotti K[5], Kerzerho V[5]

1 Company for Open Ocean Observations and Logging (COOOL), Saint Leu, La Reunion, France
2 IFREMER, MARBEC, Sète, France
3 IFREMER, DOI, Le Port, La Réunion, France
4 SATHOAN, 29, promenade J.B. Marty 34200 Sète, France
5 CNRS, LIRMM, Montpellier, France

ABSTRACT

SMARTSNAPs are a new device to aid in reducing mortality of bycatch species caught on longlines. The device is equipped with several sensors to assist in characterizing species-specific line behavior of fish caught on longlines, with the goal to detect species in real-time and release bycatch species automatically and immediately after capture, thereby reducing the risk of negative physiological and behavioral impacts and depredation, and thus lowering mortality. The SMARTSNAP1 project has recently completed with the development of a first prototype to test the proof of concept. The prototype developed was successfully deployed in both the Gulf of Lions and the waters around La Reunion, capturing 27 individuals from 10 different species on smartsnaps. Metadata about the capture, state of the fish, fishing effort, bait, and line setup were recorded with a custom-developed metadata elogger. Sensor data for each smartsnap is stored in a specially-developed InfluxDB database, and is read from a SMARTSNAP data visualisation dashboard, to assist in comparing and analysing sensor signals. Algorithms are beginning to be developed to determine important fishing events (capture, line fighting, death), and will continue to progress towards species-specific detection. Improvements to the device are planned in future projects.

INTRODUCTION

Although longline fishing is a selective fishery compared to other gear types, unwanted bycatches and accidental captures of sensitive species are observed and have ecosystem impacts. Bycatch can be returned to sea; however mortality rates are unknown and survival is not guaranteed. To avoid bycatch, methods are employed to alter the selectivity of the longline that are either passive avoidance measures, e.g. circle hooks to avoid catching sea turtles, or active repellants, e.g. acoustic pingers to reduce marine mammal interactions. These solutions are often only effective on a limited range of species. Once hooked, animals are subject to stress responses, fighting the line, which can lead to physiological impairment and exhaustion, behavioral impairment, and lower survival rates upon discard (Barton, 2002; Guida et al., 2016; Gallagher et al., 2017) as well as the risk of depredation while waiting to be hauled back.

The aim of the SMARTSNAP1 project is to develop an innovative technique for reducing by-catch mortality in longline fisheries by quickly and automatically releasing unwanted catches. This will be achieved by fitting the hooks with electronic systems capable of identifying the species caught and automatically releasing the hook from the line when bycatch species are identified. The SMARTSNAP1 project, a partnership between CNRS-LIRMM, IFREMER DOI and MARBEC, SATHOAN and COOOL, and co-financed by the European Fund for Maritime Affairs (FEAMP) and Fisheries (FEAMP), and France Filière Pêche, Association of the French maritime fishing industry (FFP) under measure 39 "Innovation in the fishing industry linked to the conservation of the sea's biological resources", aims to provide a proof of concept for this type of electronic system tested on the longlines deployed by professional fishers in the waters around La Reunion and in the Gulf of Lions.

Anecdotal evidence from fishers and several studies (e.g. Talwar et al. 2020; Brownscombe et al., 2014; Whitney et al., 2016b; Bouyoucos et al., 2017; Gallagher et al., 2017; Guida et al., 2017; Bouyoucos et al., 2018) have shown that different species behave differently when caught on a line, and fishers can identify some species that are hooked based on the line behavior. Using this theory, the SMARTSNAP project aims to identify species caught based on line behavior using an electronic device, or SMARTSNAP, positioned close to the longline snap and equipped with sensors that record the line movement (accelerometer, temperature, pressure, magnetometer). These data are then analyzed to characterize the line movement relative to a specific species. When an individual from a bycatch species is detected, the hook is automatically released and the individual is released from the line (Figure 1).

In this paper, we describe the first SMARTSNAP prototype and the first results from the field trials that succeeded in providing the proof of concept for this innovative tool.

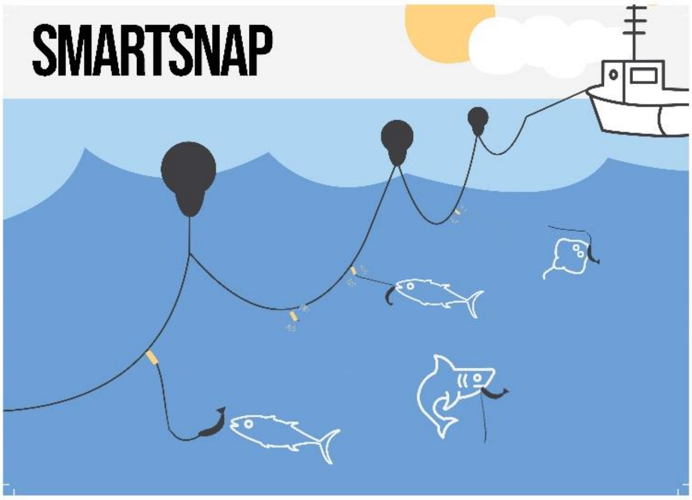


Figure 1. The principle of SMARTSNAP is to equip the longline with the SMARTSNAP device equipped with sensors to record species-specific capture behavior and release the hook of individuals of bycatch species.

METHODS

Device prototype development

LIRMM and IFREMER led the development of the electronics and housing of the SMARTSNAP1 prototypes. The SMARTSNAP device is simply an watertight housing with a motherboard connecting a battery and multiple ready-made sensors bought “off the rack”. This type of sensors were selected for the first SMARTSNAP prototypes as the beginning of the project (end 2021) coincided with the global shortage of the supply of electronic chips in 2021, making a customized electronic board infeasible for the timeline and budget of the project.

Housing

The housing was developed using PVC pressure pipes, qualified for 15 bar (153 m; Figure 2), with the tube closed on one side by a dead-end plug, and the otherside by an inspection plug. The casings were tested at sea between 90 and 300 m depths. Further tests were conducted in the hyperbaric chamber at the IFREMER station in Toulon, demonstrating a pressure resistance of up to 37 bar, i.e. 378 m.

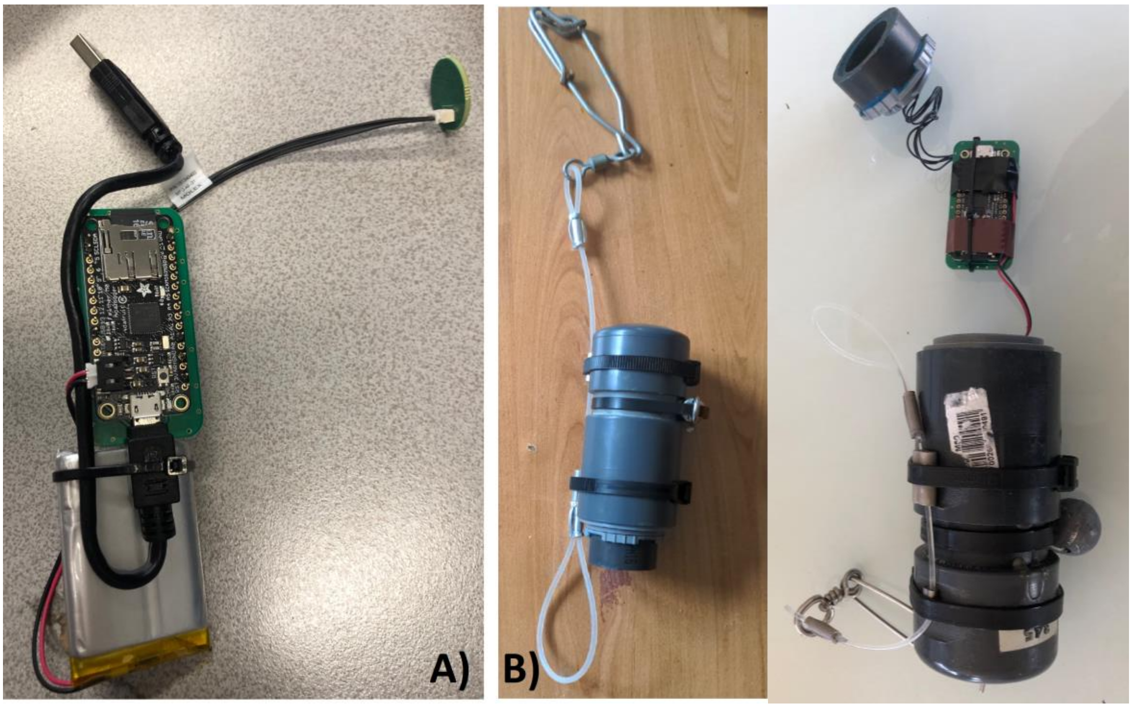


Figure 2: Prototype after assembly and fitted with a leader and a snap for deployment, assembly of the device.

Electronics design and validation

We designed and manufactured a pressure sensor board connected to the interface board via a 4-pin ribbon cable (see Figure 2A). An O-ring is placed on the sensor cap and the sensor card is sealed into the back of the plug. The assembled device with the pressure sensor and plug were tested in vitro and in situ and over long periods and was determined to be sufficiently robust to withstand marine deployment.

Prototype production

We manufactured 180 devices in preparation for the 2023 deployments. Each prototype was individually tested for a minimum of 24 hours, before each deployment. Charging and data transfer are conducted via USB hub.

Data collection

Deployments

An initial campaign was carried out on Reunion Island between February and March 2023 on the longliner "La petite crevette". The devices were then brought back to Sète for a campaign in April 2023 on the longliner "les 3 frères 2", and a final campaign was carried out on Reunion Island in May and June 2023 on the longliner "l'Ichtys". Further deployments were constrained by weather and fish availability.

Figure 3: Smartsnap trip on Reunion Island on the longliner "La Petite Crevette".

Interactive tablet application for metadata collection

Informative metadata, such as the species captured, whether the individual experienced depredation, the bait used, the state of the bait and the fish caught, the line setup, including buoy and snap position, are essential for post-deployment analysis to understand the fishing events, catches and species profiles observed by the SMARTSNAPs. COOOL therefore led the development of a metadata logging application to facilitate the collection of metadata during at-sea operations, and to standardize the format in which metadata are saved to simplify its use and facilitate analyses (Figure 4). Furthermore, important information on the mission (e.g., date, operator, number of smartsnaps deployed) can also be entered and recorded. The start time of line and snap deployment is recorded in real time with the data entered by the user and includes the time at which each line element entered the water, making it possible to estimate the immersion time, an important indicator of fishing effort. The user can also indicate the end of the line set, which is then associated with a time stamp.

We encountered a few problems with on-board data logging, and the limitation to Windows OS-based devices will be resolved in the next iteration.

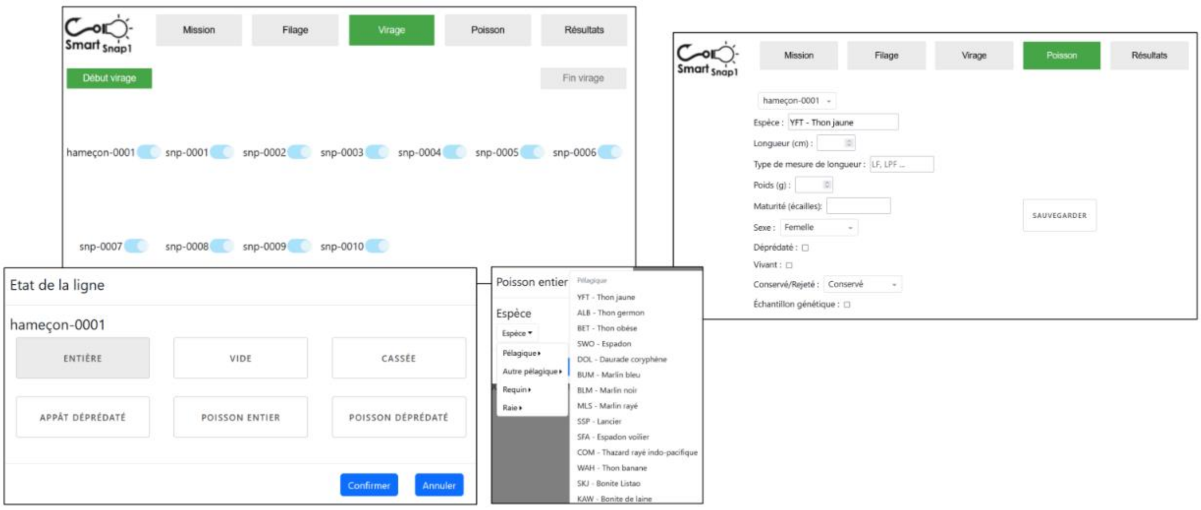


Figure 4. Screenshots of the metadata e-logger, which allows the user to record in real-time the line setup and haul back, capture species, bait type, state of the fish and bait upon haul back, mission information, and effort information important for the development of algorithms to determine species-specific line behavior.

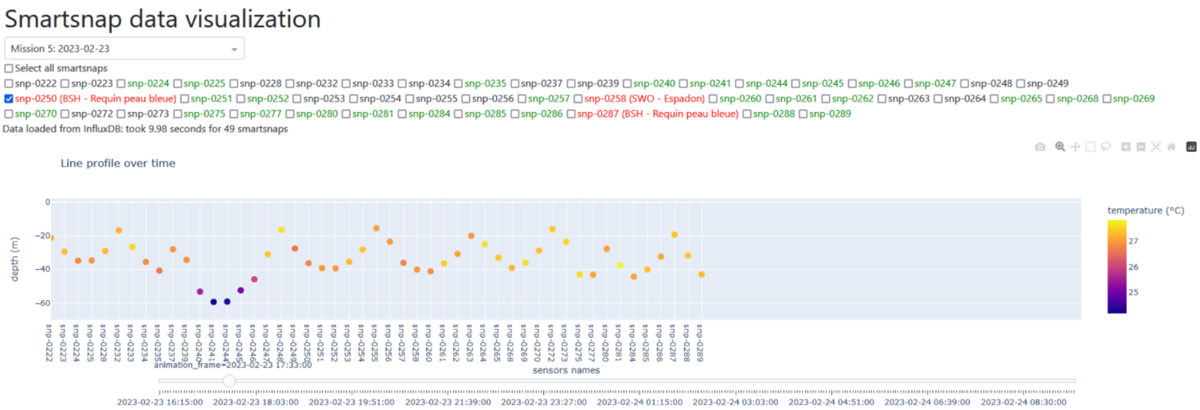
Data visualization and analysis

Database and human-machine interface

To securely store, manage, visualize and analyze the data collected during the SMARTSNAP project, COOOL led the development of a dedicated InfluxDB database. A Python script was created to transform the raw sensor data (.txt format) into a database. This data table is associated with the metadata and then transferred to the Influxdb online database.

A dashboard was developed to easily visualize the sensor data collected during SMARTSNAP deployments, and to enable the project team to quickly compare smartsnaps data with each other through a panel of figures and tables. The dashboard was created using Python's Dash framework (Figures 11,12). This framework is specially designed for creating data visualization web applications.

The dashboard enables data stored on the InfluxDB database to be viewed by fishing campaign. Several dynamic graphics display on the dashboard to visualize the relative position of each smartsnap on the line and the evolution of its depth (y) and temperature (colored circle) over time



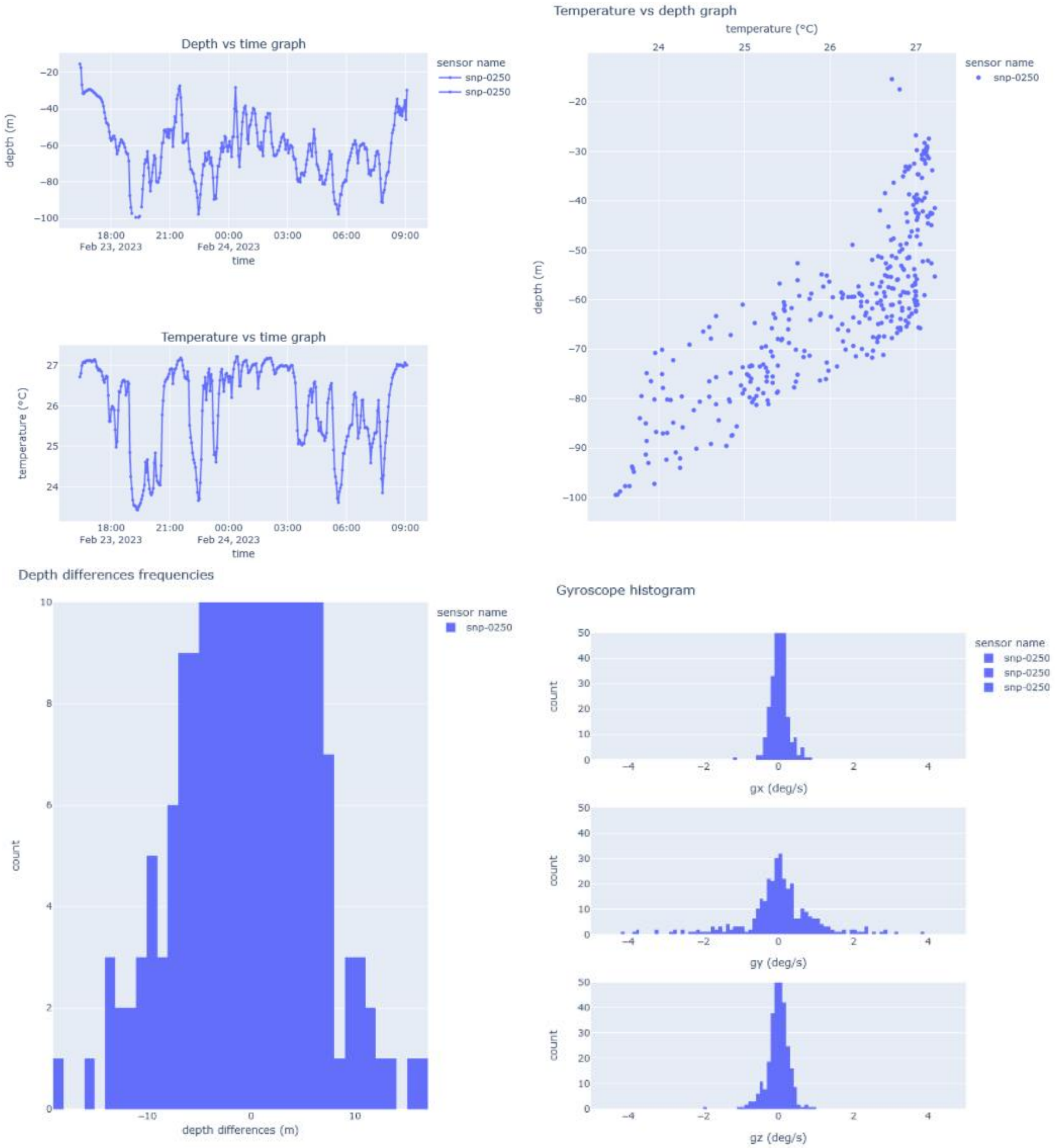


Figure 3. Screenshot of the SMARTSNAP data visualization dashboard.

(x). Algorithms were developed to predict fishing activity based on the vertical displacement of the device. Metadata collected during the campaign (more below) are associated with the smartsnap data to enable the characterisation of species-specific line behavior. The dashboard graphics can provide individual sensor information or combined information from the various smartsnaps and can be viewed on the dashboard to facilitate identification and comparison of depth and time patterns (top left), temperature vs. time (middle left), temperature vs. depth (top right), depth displacement frequencies (bottom left) and gyroscope measurements (bottom right) (Figure 3).

RESULTS

On the three fishing campaigns over the two sites, we were able to capture 27 individuals on the smartsnaps. Four species had several individuals caught, required for species-specific line behavior analyses, i.e. snoek (n=5), swordfish (n=3), blue shark (n=4) and bluefin tuna (n=5).

Table 1: List of fish caught with a smartsnap.

Espèces	Nombre	Lieu
Albacore tuna (ALB) *Thunnus alalunga*	1	La Réunion
Swordfish (SWO) *Xiphias gladius*	3	La Réunion
Snoek (SNK) *Thyrsites atun*	5	La Réunion
Ray	2	La Réunion/Golfe du Lion
Actinopterygii	1	La Réunion
Blue shark (BSH) *Prionace glauca*	4	La Réunion/Golfe du Lion
Dolphinfish (DOL) *Coryphaena hippurus*	1	La Réunion
Barracuda (GBA) Sphyraenidae	1	La Réunion
Ocean sunfish (MOL) *Mola mola*	1	Golfe du Lion
Atlantic bluefin tuna (BFT) *Thunnus thynnus*	8	Golfe du Lion

In these initial analyses, we are able to identify general line behavior using only pressure data, including line fighting (sharp spikes up and down in pressure/depth; Figure 5a) and death (slow and deep sinking; Figure 5b).

Analyses of species-specific behavior are ongoing and will be presented in the future.

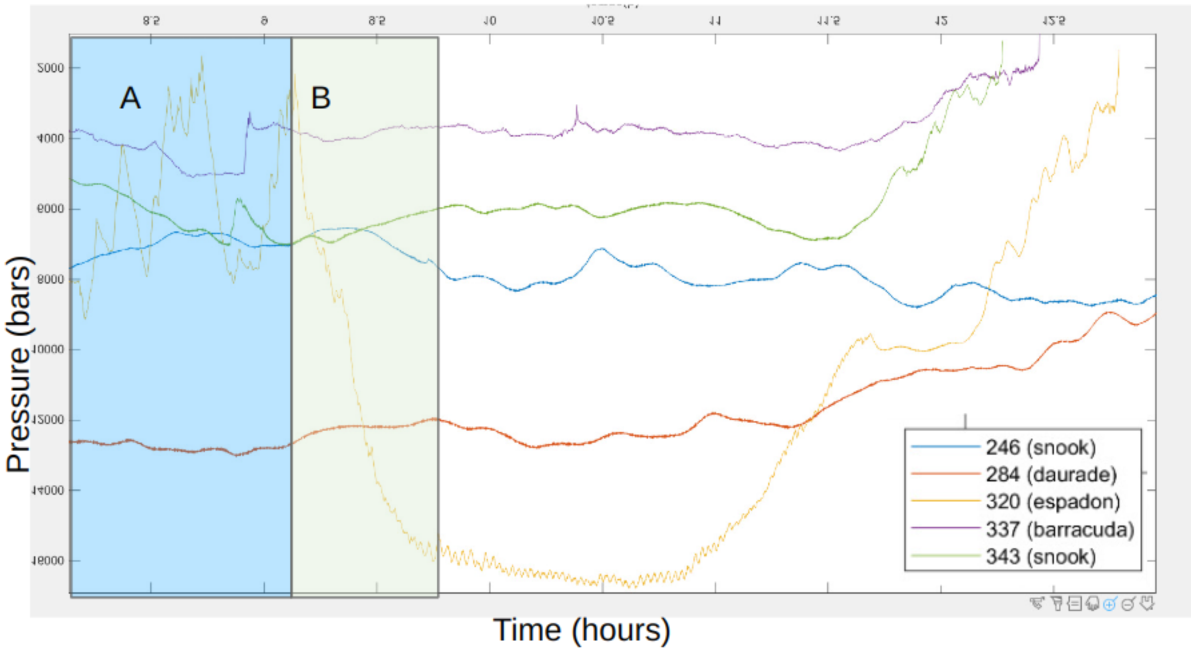


Figure 5. Pressure over time for 5 individuals of different species captured on a smartsnap, noting behavioral changes in the pressure sensor when the individual is fighting (A) and with mortality and sinking (B). Note that the y axis has been flipped to better visualize pressure as depth.

DISCUSSION

The objective of the SMARTSNAP1 project was to initiate the development of a device to reduce by-catch mortality by instrumenting fishing lines to identify the species caught so that individuals can be released quickly. To achieve this, we developed a watertight device containing several sensors (pressure, temperature, accelerometer, magnetometer, gyroscope). We manufactured 180 devices which enabled us to collect data on longline catches in the Gulf of Lion and around Reunion Island. Twenty-three individuals of 10 different species were caught on the SMARTSNAP1 prototype.

Preliminary analysis shows a difference in behavior between catches. In addition, an application was developed to collect the metadata (time, position, order of prototypes deployed, type of bait, etc.) needed to analyze the data. A database and a human-machine interface were also developed. These elements are essential when collecting a large amount of data.

These positive results will enable us to move ahead with the further development of the device. We plan to submit further projects, with the aim of manufacturing a larger quantity of devices and developing additional functions such as automatic release or real-time feedback to the fishers.

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